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Materializing Policies for Sustainable Use and Economy-wide Management of Resources:

Biophysical Perspectives, Socio-Economic Options and a Dual Approach for the European Union

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Abstract

Policies for Sustainable Use and economy-wide Management of natural Resources (SUMR) throughout the production and consumption system are faced with environmental and socio-economic requirements and regulatory constraints. Based on empirical findings of ongoing trends of resource use, decoupling from economic growth, and transregional problem shifting, the paper outlines a potentially sustainable biophysical basis for production and consumption in the EU. It discusses the main challenges for the major resource groups, describing the specific and the common tasks with regard to biomass, fossil fuels, metals, non-metallic minerals. Adopting a medical metaphor, it suggests that policies for SUMR should follow a dual approach reflecting the long-term need for a main cure of the socio-industrial metabolism in form of a "conditioning" towards a more mature, resource efficient, and renewables based constitution on the one hand, and a fine tuning of selected material flows (e.g. for optimized recycling and control of hazardous compounds) on the other hand. Both strategies are deemed complementary and necessary to reduce environmental impacts and increase the utility of material use. Action required is exemplified with regard to the three pillars of SUMR, i.e. improved orientation, information and incentives.

Key words: Material efficiency, dematerialization, renewables, socio-industrial metabolism, resource use, environmental impacts, sustainable production & consumption, bioeconomy

Zusammenfassung

Eine Politik für zukunftsfähige Nutzung und wirtschaftsweites Management natürlicher Ressourcen im Produktions- und Konsumsystem (kurz Ressourcenpolitik) steht vor umweltbezogenen und sozio-ökonomischen Anforderungen und regulatorischen Schwierigkeiten. Vor dem Hintergrund empirischer Befunde über laufende Trends der Ressourcennutzung, der Abkoppelung vom Wirtschaftswachstum und der trans-regionalen Problemverlagerungen, umreißt der Artikel eine potenziell nachhaltige biophysische Basis für Produktion und Konsum in der EU. Er diskutiert die wesentlichen Herausforderungen bezogen auf die Hauptgruppen stofflicher Ressourcen, wobei die spezifischen und gemeinsamen Aufgaben bezogen auf Biomasse, fossile Energieträger, Metalle und nicht-metallische Minerale beschrieben werden. Unter Verwendung einer medizinischen Metapher wird vorgeschlagen, dass eine Ressourcenpolitik einen dualen Ansatz verfolgen sollte, der zum einen die langfristige Notwendigkeit einer Gesundheitskur des sozio-industriellen Stoffwechsels widerspiegelt zur Verbesserung der "Kondition" in Richtung einer reiferen, ressourceneffizienteren, und auf erneuerbaren Ressourcen basierten Konstitution; und der zum anderen, eine Feinsteuerung ausgewählter Materialflüsse verfolgt (z.B. zur Optimierung des Recycling und der Gefahrstoffkontrolle). Beide Strategien werden als komplementär und notwendig erachtet, um schädliche Umweltwirkungen zu vermindern und den Nutzen des Materialeinsatzes zu erhöhen. Erforderliche Umsetzungsmaßnahmen werden beispielhaft aufgezeigt für die drei Säulen einer Ressourcenpolitik: bessere Orientierung, Information und Anreize.

Stichworte: Materialeffizienz, Dematerialisierung, Erneuerbare Ressourcen, sozio-industrieller Stoffwechsel, Ressourcennutzung, Umweltwirkungen, nachhaltiges Produzieren und Konsumieren, Bioökonomie

Contents

Introduction

Sustainable Use and economy-wide Management of natural Resources (SUMR) goes beyond the question of how to manage forests, coastal systems or marine fish stocks; it is about the question of how to develop the physical basis of society and economy through restructuring the use of biotic and abiotic resources throughout the production and consumption system in a sustainable manner.

Economies use nature as a resource in different ways, mainly as a source of raw materials and energy, as a sink for pollutants, and as living space. Here we focus on the use of all material resources (biomass, fossil fuels, metallic minerals, non-metallic minerals)[1] also considering land use.

There is a growing awareness that industrial societies will have to change the way they use natural resources and to develop more sustainable production and consumption patterns (UN 2002). Environmental constraints, price fluctuations of raw materials, a growing disparity of global resource use, and an increasing risk for international security give rise to concern. Smarter means than military action is required to secure supply for material welfare.

Reducing the dependance from material resource requirements may be regarded the overarching challenge for the world economy in this century. This holds especially for those economies, which have become junkies with regard to non-renewable resources like oil and and metals. A key strategy to reduce that dependance is to make more out of less, i.e. to increase resource efficiency. At the policy programme level, international institutions and national governments have introduced goals such as factor 4 to 10 to increase resource productivity[2]. Some countries have set specific targets, e.g. Germany[3] and Japan[4], however, concrete policies are still under development.

1 Water is covered implicitely in the management prinicples derived; the existing water framework directive provides a thorough basis for sustainable management of water at a river basis level.

2 These goals have been proposed by Schmidt-Bleek (1992) and Weizsäcker et al. (1995) for long-term orientation of industrial countries; for interpretation see Bringezu (2002) and for adoption see EEA (2005) n. The German sustainability strategy demands for an increase of energy and raw material productivity by a factor of 2 between 1994 and 2020; the indicator raw material productivity however captures only a part of material resource requirements; it does not include biomass nor unused domestic resource extraction and resource requirements of imported semi-final and final products (both also addressed as “domestic and foreign hidden flows”.

4 Within the framework of a sound cycling economy, Japan decided to increase material productivity by 40% between 2000 and 2010; the indicator is based on Direct Material Input, i.e. it includes biomass but excludes domestic and foreign hidden flows.

The EU, under its 6th EAP, developed a thematic strategy on sustainable use of natural resources (TSSURE) (CEC 2003, 2005a)[5]. It shall complement strategies and measures on recycling and Integrated Product Policy, provide an overall framework for sustaining the resource basis of the EU, and help to fill gaps, heal deficiencies and support the integration of environmental concerns into sectoral policies. TSSURE aims to “improve understanding and knowledge of European resource use, its negative environmental impact and significance in the EU and globally”; besides improved methods and indicators for monitoring, and support for awareness raising, it shall also “foster the application of strategic approaches and processes both in economic sectors and in the member states”.

TSSURE stresses the ulimate goal to reduce the environmental impacts of resource use (rather than resource use per se). A double decoupling is suggested for sustaining resource use: first, decoupling of economic growth from resource use (through increased resource efficiency), and second, a decoupling of resource use and its environmental impacts (through mitigation of resource specific impacts) (FIGURE 1). Both effects combined are expected to enhance “eco-efficiency”. Focussing on the (direct) mitigation of impacts, SSURE recommends that national and sectoral resource policies and management should start prioritizing material flows with regard to environmental impacts, and search to control those impacts material by material on a life-cycle-wide basis.

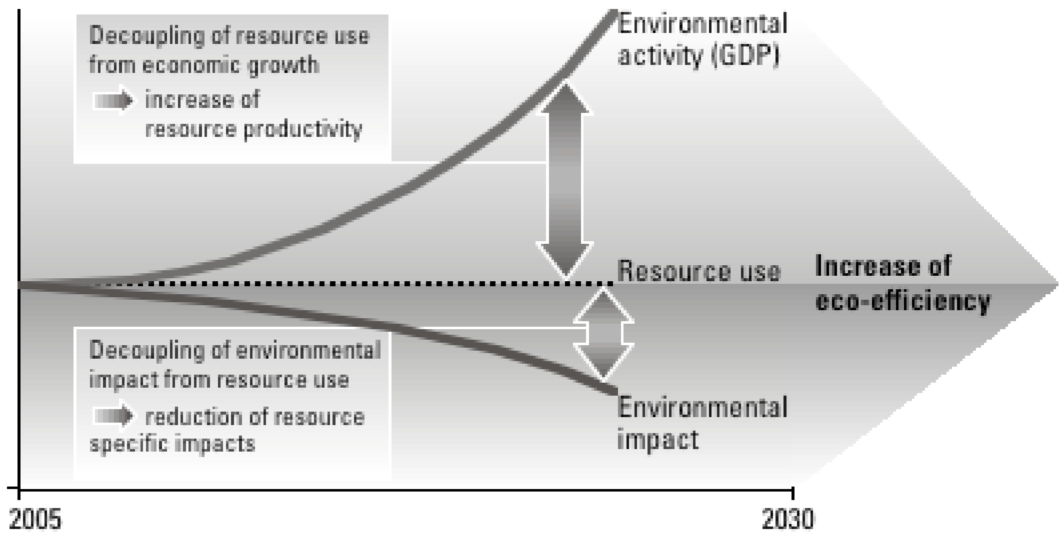

FIGURE 1: The European Resource Strategy aims at a double decoupling (CEC 2005a).

5 Various documents can be found on: http://europa.eu.int/comm/environment/natres/index.htm

In this paper we argue that the material and impact specific approach is necessary but needs to be complemented by a generic approach focussing on increased resource efficiency and reduced use of all primary resources (on a life-cycle-wide basis). We consider the latter strategy as an effective *means* to mitigate the impacts of resource use (rather than an aim in itself). Resource use of an economy as a whole is inextricably interwoven with various environmental impacts which altogether cannot be effectively mitigated without a reduction of resource consumption and an increase of resource efficiency. A resource policy which would only orient towards selected material flows and impacts would probably induce substitution effects and enhance problem shifting between different materials; and because not all direct and indirect environmental impacts can be quantified and because impacts in other regions are either lesser known and/or assigned lower priority than impacts nearby, such a resource policy would run a high risk of problem shifting between different impacts and regions.

SUMR goes far beyond environmental policies. Reducing the dependance from raw materials through more efficient use has been recognized as an option to trigger innovation and foster competitiveness[6]. Resource efficiency thus becomes a key strategy also for economic, industrial and technology policies, but also for social policies (through securing employment).

In the past, environmental policies have already triggered technological and institutional change and the establishment of new markets such as for cleaner production, recycling economy, renewable energy, and greener products. At the same time, it becomes more and more obvious that the orientation towards single environmental problems and individual technologies opens the caveat of problem shifting. For instance, cleaning production by filters and catalysts may successfully reduce certain pollutant releases, however, often at the expense of other wastes occurring for the production of the cleaning equipment elsewhere. The successful implementation of the recycling economy, e.g. in Germany, has lead to a situation, in which relevant actors in industry are interested in the further generation of waste rather than in waste prevention. The generation of energy from renewable sources is coupled to a varying amount of non-renewable mineral flows (e.g. platinum group metals for fuel cells, which have a profound ecological rucksack) and, especially in the case of biomass, to land use which confronts increasing demand with global limits of availability. If greener products are defined based on the substitution of hazardous compounds in the production process, a closer look at the substitute will often reveal that is also not neutral to the environment. And an increased consumption of greener products, even if they have been designed in a material and energy efficient way on a life-cycle-wide basis, may overcompensate beneficial effects from the substitution of conventional products and lead to an absolutely growing resource use and related environmental pressure. Thus, policy measures directed to the product and company level

[6] Commission of the European Communities: Integrated guidelines for growth and jobs (2005–2008). COM(2005) 141 final; see esp. point 14

need to be supplemented by policies which provide guardrails for resource use at the macro-economic level.

A national and regional perspective may also not suffice for SUMR. As will be discussed in this paper, analysis of the European resource flows reveals an increasing shift of raw material sourcing from industrial countries to transition and developing countries, which often bear a high amount of environmental burden but profit only to a minor degree from the life-cycle-wide value added in the production chain subsequent to the extraction process.

Therefore, SUMR will have to consider the global implications of national or regional resource management. It needs to be based on a systems perspective which allows to minimize problem shifting and takes into account the development of the overall socio-industrial metabolism, i.e. the material flows from resource extraction, over manufacturing, final production, consumption, recycling to final waste disposal[7]. These flows form the bridge between human activities and environmental impacts on the one hand, and the provision of material welfare on the other hand.

In recent years considerable progress has been reached on the measurement of the socio-industrial metabolism[8]. Economy-wide material flow analysis and derived indicators (Bringezu et al. 2003) are increasingly introduced to official statistics. European institutions such as Eurostat (2001a) and the EEA (2003) as well as international organisations like OECD (2005) support harmonized accounting of materials use and productivity at the national level. Indicators have been developed which allow to describe the dynamics of the metabolic performance of countries, regions, sectors and to monitor the implications of globalization (Bringezu 2006). The debate on how to interpret the indicators for the design and control of policy measures is ongoing, and countries are in the process to set priorities on the management of the different material and resource flows.

This paper will provide an overview of the main strategies for implementing sustainable use and economy-wide management of resources while addressing the following questions:

- Which are the main objectives and key requirements for SUMR?
- How resource or material specific need SUMR policies to be?
- Which measures should be given priority?

The paper will start to define the criteria for SUMR and provide some of the main arguments why society and industry of countries like in the EU need become more

7 This corresponds to the requirement set forth in the TSSURE that environmental impacts should be considered on a life-cylce-wide basis.

8 See e.g. Ayres and Ayres (2002) and contributions therein; http://www.conaccount.net; http://waste.eionet.eu.int/mf

resource efficient and reduce primary resource requirements. It will summarize essential findings on ongoing metabolic trends, and then outline a potentially sustainable future bio-physical[9] basis for production and consumption in the EU. It will discuss the main challenges for the major resource groups, describing the specific and the common tasks with regard to biomass, fossil fuels, metals, non-metallic minerals. The paper will then discuss where material specific and unspecific strategies seem appropriate, and will finally suggest that policies for SUMR should follow a dual approach reflecting the long-term need for a main conditing of the socio-industrial metabolism towards a more mature, resource efficient, and renewables based performance on the one hand, and a fine regulation of selected material flows on the other hand.

What is sustainable use and management of resources?

The following objectives may be attributed to SUMR. It should

1. *Secure adequate supply and efficient use of materials, energy and land resources as reliable bio-physical basis for creation of wealth and well-being in industry and society;*
   the latter ultimate goal can be met by different means, and therefore, will any provision on the supply side need to be considered in conjunction with development options on the demand side;

2. *Not overload or destroy nature's capacities of reproduction and regeneration of resources and absorption of residuals;*
   these requirements reflect the essentials of the often cited management rules (Daly 1992, Barbier 1989); one should, however, be aware that thresholds can hardly be determined by means of (natural) science, but require a normative judgement on the societal (non)tolerance of changes of the environment;

3. *Contribute to safe-guard the co-existence of society and nature;*
   this criterion reflects that, on the one hand, society is dependant from nature like the stem of a tree from its roots; and, on the other hand, nature has its own right of existence, e.g. with regard to species which go extinct before they are even known;

4. *Minimize risks for national and international security and economic turmoil due to dependance on resources;*
   there is a growing risk of resource wars and intra- and international conflicts on the access to natural resources; short- to medium term shortages in commodities may hamper economic development; long-term strategies are required to reduce the risk of military conflicts, and to provide industry with reliable information on the future resource base;

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9 The term "bio-physical (in German: "biophysisch") indicates that the material basis of economies comprises biotic and abiotic resources and is depending on biological and physical systems.

5. *Contribute to a globally fair distribution of resource use and an adequate burden sharing;*
   still the disparity in resource consumption between countries is considerable, and the international trade leads to "unequal" ecological exchange in the sense that resource consuming richer countries gain higher value added while carrying a lower environmental burden in comparison to resource exporting poorer countries; thus, in terms of regional equity the relations should become more balanced;

6. *Minimize problem shifting between environmental media, types of resources, economic sectors, regions, and generations;*
   this may be the most challenging requirement, which calls for the widening of the systems perspective (in order not to overlook what has been neglected so far); as will be shown in the following, various trends of problem shifting are ongoing;

7. *Drive technological and institutional change in a way and towards a direction which also provides economic and social benefits;*
   this reflects not only the basic requirements of the three pillars of sustainability; it also points out how to find the way towards SUMR: in search for multi-beneficial options rather than in mitigating one problem after the other, i.e. by defining sustainability in positive terms rather than in a negative manner; and last but not least: in search for driving development towards the "right direction"[10], finding the "sustainability corridor", rather than by precise prescription of individual action or technological processes.

Why do we need increased resource efficiency and more sustainable use of resources?

Current resource use in production and consumption does not comply with the criteria of SUMR listed above. Current symptoms of unsustainable resource use have been described, for instance, by Millennium Ecosystem Assessment (2005), EEA (2003, 2005), UNEP (2002).

So far, scarcity of single resources has not become a major problem. The long-term price development of primary raw materials during the last century shows a steady downward trend (USGS 2004). Short-term price peaks and fluctuations were overcome by increased exploration and improved technology. Altogether, declining prices and rising demand in production and consumption are leading to increased global resource extraction and environmental depletion. Markets have failed to internalize environmental costs associated with mining, refining etc., and it seems unrealistic to expect that business as usual will change anything in this trend. There are, however, some signals which indicate that scarcity of basic or "strategic" resources like oil or base metals may

[10] Schmidt-Bleek (1993) had pointed out the importance of "directionally safe" decision making.

pose increasing economic risks due to high volatility of prices, unsecure supply, and tends towards oligopolistic market structures (Bleischwitz 2005).

In addition, there is a scarcity of resources in terms of limited biophysical capacities and societal requirements to cope with the implications of overall resource use. In other words, the volume and structure of overall resource use especially of industrial countries is unsustainable as long as it does not reduce the negative impact to the global environment (at various scales from local to continental) to a tolerable level, and adjust to a more equitable manner of international resource consumption.

The current resource use of industrial countries may not serve as a global model. If the current total material consumption of these countries were adopted world-wide this would lead to an increase of global resource consumption by a factor of 2 to 5 until 2050 (Bringezu et al. 2003). Because most of the resource requirements, usually about 90%, are naturally non-renewable[11] minerals, the current resource use is associated with a continuous change of the world´s surface and steady change of landscapes. Current use of biomass also already leads to global degradation of ecosystems. Actual land use requirements of developed regions such as the EU-15 according to their consumption of agricultural goods exceed their domestic arable land by about one fifth, and a global adoption of Western style consumption patterns would lead to an expansion of intensively cultivated land at the expense of the rest of natural ecosystems (Bringezu and Steger 2005). Thus a global adoption of the production and consumption patterns of industrial countries would be a major threat to the natural environment and our resource and living base. Therefore, countries and regions such as the EU *need* to use both renewable and non-renewable resources in a significantly more efficient manner, in order to reduce current natural resource consumption and give room to the development of the rest of the world.

The increase of resource efficiency also provides *chances* with regard to the socio-economic development within the EU and comparable industrial regions (Bleischwitz and Hennicke 2004). The so-called Kok committee of the EU Commission was in charge of evaluating the Lisbon process which had formulated the objective that the EU becomes the world most competitive economy. The committee came to the conclusion that resource efficiency should be regarded as the key factor to enhance innovation and increase competitiveness (CEC 2004a). The European Commission discussed the ways how to combine environmental protection with economic growth (CEC 2004b). The "Integrated guidelines for growth and jobs" then adopted the strategy to increase resource efficiency (CEC 2005). In the EU, different policies exist which could contribute to making Europe the most resource and energy efficient (and thus most competitive) region of the world (Rocholl et al. 2006), although these policies seem rather scattered and are still lacking an overall target driven and consistent approach.

[11] Within time scales relevant for human and biological systems' adaptation.

With respect to the fact that some major economies of the world are increasingly being faced with symptoms of stagnation, the question arises in which direction the horizon for future development will open up. Here, some considerations on the metabolic dynamics may be supportive.

Major metabolic trends

Economies are tied by physical strains to the natural environment by resource extraction on the input side, and waste release on the output side (FIGURE 2).

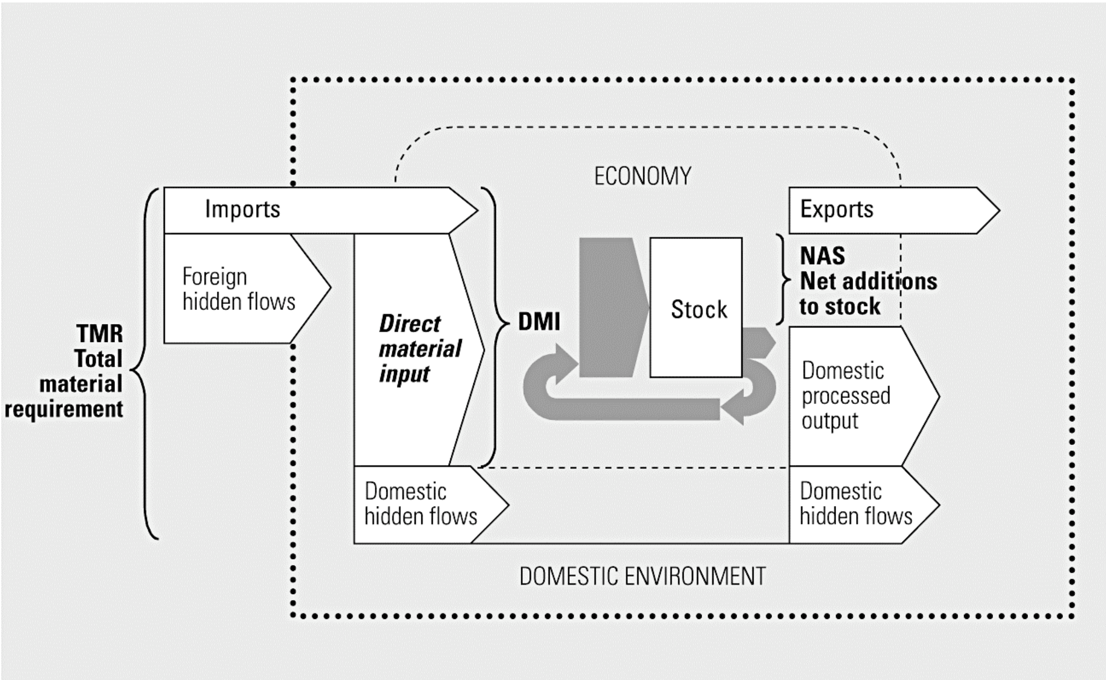

FIGURE 2: Scheme of the socio-industrial metabolism and derived indicators (after Matthews et al. 2000)

There is some evidence, however, that the dependance of economic development from natural resource consumption declines (Bringezu et al. 2004, EEA 2003, 2005, Eurostat 2001b)[12]:

- In nearly all economies studied, a relative decoupling of material use (measured as Direct Material Input DMI) and GDP has been proven. That means that economies

[12] For data and interpretation of economy-wide material flow accounts and derived indicators see: e Management (ETC-RWM): http://waste.eionet.eu.int/mf

are already on the road towards increased materials productivity, and that the market to a certain degree already favours progress towards this end.

- High values of GDP and thus prosperity are possible at different levels of material use and thus waste generation; the factors responsible for the differences are currently under scrutiny.

- So far there is no empirical evidence for an automatic absolute dematerialization in the course of economic development; the very few instances where DMI and TMR (total material requirements) were reduced had been coupled to policy interventions; this indicates that certain changes of the policy framework seem necessary in order to reach absolute reductions of resource use and waste generation and to approach sustainable levels.

- Industrial countries tend to shift primary production to other regions; domestic mining is abandoned and metal resources are increasingly being imported; at the same time, the ecological rucksacks of mining, unused extraction linked to landscape transformation, hazardous mining waste etc., grow. In the course of globalization the EU has not only increased its net physical trade balance (imports more material than it exports), but the net primary resource requirements of foreign trade have been growing to an even higher extent (FIGURE 3). Thus the environmental pressure of total material requirements are increasingly shifted to other regions, esp. to developing and transition countries (Schütz et al. 2004).

- Net addition to material stock is still significant in all countries studied (Eurostat (2001b); Bringezu et al. (2003)); the world technosphere is in a physical growth phase; there are, however, in a number of developed countries first signs of a possible saturation of buildings and infrastructures are visible (regional over-capacities in the dwelling and office building markets, increased demolition of buildings, liquidation of construction companies, higher unemployment of construction workers). From theoretical metabolic considerations, there must be a flow equilibrium between material input and output of the technosphere in the future (zero net addition to stock) and a steady state between the construction of new buildings and the deconstruction of old ones (Bringezu 2000, 2002). The open question is when and at which level this equilibrium will occur. One may assume that old-industrialized developed countries with a stable population will reach this maturation phase earlier than industrializing developing countries with increasing population.

Considering all these trends, one may arrive at the conclusion that a deliberate policy development fostering the increase of resource efficiency and the shift towards renewable resources (either biobased with sourcing from sustainable cultivation, or recycling based) will aim at multiple win solutions (for the economy, the environment and society). Having in mind that the growing final demand in transition and developing countries is going to be the major driving force of global resource demand, there is no alternative than to speed up the technological and institutional development in all countries in order to further gain prosperity and well-being with significantly less natural resources than through the unsustainable patterns of production and consumption introduced so far. The current metabolic profile of the so-called “developed” countries is under transition, and will certainly not be the end-point of development also in these countries. Their task will be to design the policy framework in a way which supports transition towards a higher degree of metabolic maturity.

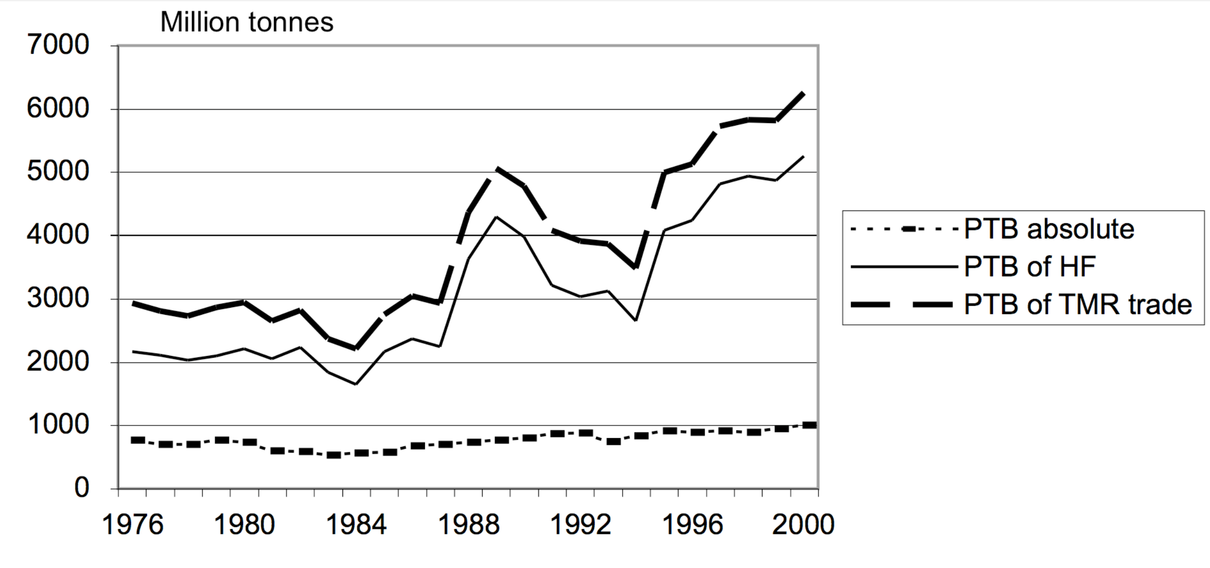

FIGURE 3: Dynamics of the physical trade balance (PTB) and net primary resource requirements of foreign trade of EC/EU-15 (Schütz et al. 2004). TMR = Total Material Requirement, HF = hidden flows (also termed “ecological rucksacks” or “indirect flows”).

Where will the avenue to future open up?

It is not possible to forecast in detail what a future metabolism of economies will look like. Technological progress, institutional changes, behavioural variances are continuously (and in the short-term also in the form of little quantum heaps) changing the physical shape of society and economy. Nevertheless, one may outline some basic features which may be regarded as essential elements on the way towards a more sustainable socio-industrial metabolism compared to status quo.

A few basic conditions will have profound consequences in the course of their implementation. Bringezu (2002) has outlined them for the example of the European Union.

(1) Approaching the flow equilibrium of the built and natural environment through reduced demand for materials stocked in additional buildings and infrastructures will

significantly reduce primary materials requirements, esp. of non-renewables, and diminish the generation of construction and demolition waste on the long run.

(2) Phasing out the use of fossil fuels for combustion in order to mitigate climate change will also contribute to a significant reduction of non-renewable resources (the fossil fuels and their rucksack flows).

(3) The use of biomass needs to be adjusted to sustainable ways of cultivation and harvest. On a global level, measures will have to be foreseen that the further expansion of arable land (e.g. due to increasing demand for biofuels) will come to a halt in order to conserve a minimum of natural forests and grassland, its biodiversity, and its various functions.

In FIGURE 4, long-term targets[13] according those three conditions have been taken as a basis for stoechiometric calculation of a sustainable socio-industrial metabolism. Interestingly, the reduction of NAS to zero and a reduction of fossil fuel use by 90% would nearly lead to a reduction of the input of all non-renewables by a factor of 10.

It seems important to note that those “conditions” are not just requirements formulated in order to cope with environmental and socio-economic problems. In addition, they seem to be in line with an evolutionary development of the metabolism of society, which has been subject to significant changes in the past (hunter/gatherer, agricultural, industrial societies) and may be expected to undergo significant changes in the future (information, well-being societies etc.). When population levels in the various regions have stabilized and requirements for dwelling, working and mobility will be met by adequate infrastructures then there will be no need for further growth of the built environment. In addition, continuous expansion of the technosphere is limited through competitive land use which is mainly required for food and feeding purposes and is expected to serve also for nature conservation. For these rather simple but fundamental reasons one may conclude that the current phase of development of industrial countries (and the world economy as a whole) is still in a rather early phase of physical expansion which will be superseded by a phase of metabolic maturity where material flows will be to a much higher degree than today internal recycling flows, and there will be vivid activities of physical growth and decline at various places of the world which altogether will be in equilibrium[14]. That flow equilibrium will comprise input and output flows from and to nature which are significantly lower than today´s resource extraction and waste disposal.

If the hypothesis is right that the socio-industrial metabolism evolves towards higher degrees of maturity, a critical argument could be that socio-economic development will automatically lead towards this end and no policy intervention would be necessary. As a

13 Relating to a period of 50 to 100 years.
14 Note that this physical equilibrium may not hinder the monetary flows to grow further, esp. as a consequence of continued increase of materials efficiency, at least for a certain longer period of time.

matter of fact, however, especially prosperous societies tend to preserve policy conditions, production and consumption patterns which they experienced as successful in the past, expecting that they may also be the recipe for success in the future.

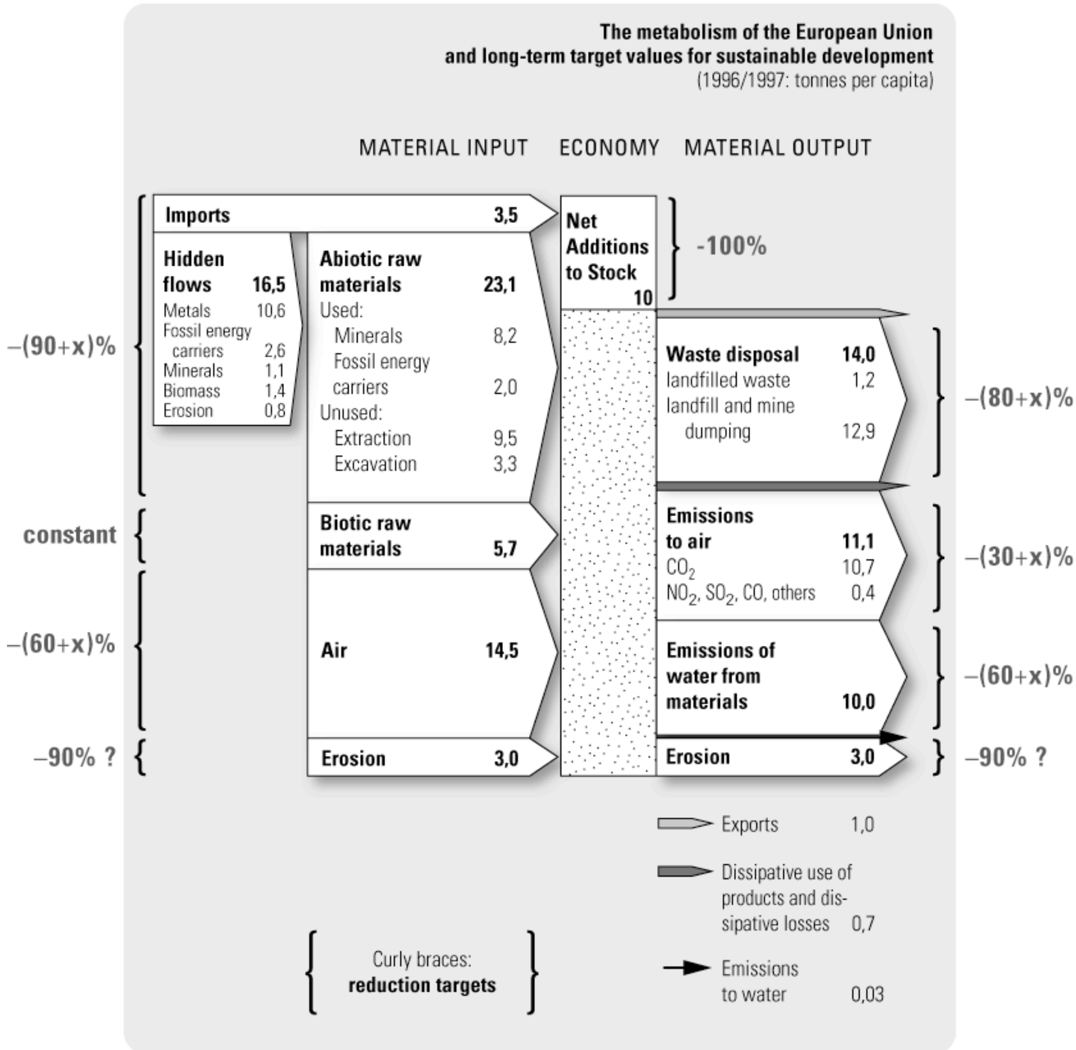

FIGURE 4: Long-term targets for developing a sustainable socio-industrial metabolism of the European Union (Bringezu 2004)[15]

This assumption, unfortunately, is only valid under constant environmental conditions; instead, the environmental and socio-economic conditions are rapidly changing on a global scale, and conservation of adequate living and working quality will require significant changes. Yet, industry lobbies representing main stream thinking and state-

15 Note that the long term targets consider that fossil based emissions to air are reduced by 90%; the lower percentage given comprises the biomass based emissions (under flow equilibrium conditions it is assumed that the input of biomass will be finally transformed by respiration or incineration)

of-the-art technology work to conserve framework conditions favourable for business as usual. Moreover, in many cases they succeed in finding state subsidies for outdated production which is neither competitive for economic reasons nor sustainable with regard to long-term requirements. As a consequence, the inherent retardation of the learning processes of societies leads to a situation where several obstacles impede the evolution towards SUMR. To overcome that deadlock, targeted action is necessary.

General guidelines for sustaining the socio-industrial metabolism

Against that background and with regard to the requirements for SUMR, the following guidelines can be considered to provide orientation for the transition of physical economies such as the EU's towards sustainability:

1. Reduce the primary materials requirements (which determine physical expansion and emissions and waste);
2. Increase the share (!) of regenerated material input, i.e. the proportion of regrown biomass and recycled minerals to total material used;
3. Mitigate the physical expansion of the technosphere, limit construction of additional buildings and infrastructures and prepare for a flow equilibrium of the materials stock, through increased renovation and refurbishment;
4. Improve the international balance of burden sharing, reduce the disparity of consumption of natural resources and the growing shifts of environmental burden from resource consuming to resource exporting countries;
5. Increase resource productivity in order to provide more economic value added and social well-being with less consumption of resources while lowering environmental burden and contributing to improved socio-economic performance (e.g. innovation/ competitiveness, employment).

Major types of resources are challenged in different ways

Although all types of material resources need to be used much more efficiently in the future, the major types of resources also differ with regard to main problems, future perspective and regulatory status quo (see also Moll et al. 2005a).

Biomass

The current use of biomass is characterized by overexploitation of natural productive capacities, e.g. by fisheries, and overload of the environment by inefficient use of fertilizers, and the extension of arable land at the expense of natural ecosystems and with a high risk of land degradation (UN 2005). The main challenge for agriculture, forestry and fisheries is to develop and orientate towards sustainable modes of cultivation and sustainable yields. In some countries, progress is being made towards this end by introducing standards for organic farming, labels for sustainable forestry, and industry has also indicated self-commitment in applying standards for own products stemming from integrated agriculture and fisheries respecting sustainable yield thresholds.

Biomass will be the dominating resource basis for the future. With respect to the overall use of biomass by the EU the task is not to reduce the quantity (neither to increase it significantly), rather to improve the quality of material flows with respect to environmental pressure on the one hand and multi-functional services of land use provided on the other hand. SUMR may be expected to contribute to

- stabilize the use of net primary production,
- increase the share of sustainably cultivated biomass (certified agriculture, forestry, fisheries and aquaculture).

For that purpose, action is required to
a. raise productivity per hectare while minimizing losses e.g. of nutrients, i.e. increase resource efficiency of production,
b. optimize nutrient flows from biowaste, sewage and ashes back to agriculture while using energy content of biomass residuals and controlling the flow of hazardous components such as pharmaceutical compounds e.g. in sewage sludge,
c. reduce the proportion of animal based production and consumption to provide room for biomaterials[16],
d. provide basic food and non-food products on an intra-continental base and limit the international trade to special agricultural goods such as coffee,
e. increase the resource and material efficiency along the production-consumption chain.

Fossil fuels
The major threat associated with the use of fossil fuels are the consequences of combustion and the resulting greenhouse gas emissions. Climate change mitigation policies have been induced by the UNFCCC and Kyoto Protocol process, and certain follow-up activities are underway. What has been neglected so far is that the extraction of fossil fuels is linked to a significant landscape change at various places over the world esp. through coal mining. Although some of the extracted non-energy material is used for infrastructures, it does not seem realistic to expect that overburden and extraction waste of fossil fuel mining could to a significant extent be used for other purposes. Ways to finally deposit carbon dioxide through sequestration also seem to be rather limited with regard to available volume of underground caverns or are associated with high risks (e.g. submarine deposition).

[16] Bringezu and Steger (2005) describe the global competitive land use of biofuels and food&feed production in the EU.

The major tasks also for SUMR is to contribute to
- the long-term phase out of combustive use of fossil fuels,
- a limited use of fossil fuels for non-energy, material purposes with subsequent energy use and carbon sequestration.

These objectives can be reached through a combination (Wuppertal Institute/GTZ 2004) of

a. increasing energy and materials efficiency in production and consumption,
b. a shift towards renewable, resource extensive and low risk energy carriers.

The currently booming biofuels may substitute only for a limited share of fossils, due to land use requirements competitive both for different energy purposes (electricity, heating, and transport fuels; DLR/ifeu/Wuppertal Institut 2003) and to other land use for food, feed, fibres, nature conservation etc. (Bringezu and Steger 2005).

Metals and industrial minerals

The demand for metals is continuously increasing (with a few exceptions such as lead, cadmium, mercury). In recent years, developing and transition countries such as China boost the markets for iron and steel and other metals. Some of the metals are required for construction and the building of infrastructures. Especially those countries with a rising demand for private and office buildings, roads and railways will contribute to a growing global demand. Industrial economies such as the EU are increasingly producing base metals and manufactures based on imports of raw materials from developing countries, and they export a rising amount of metal products to the rest of the world. The disparity between countries with regard to the asymmetry of economic gains and environmental burden is going to grow. Recycling may contribute to reduced resource consumption, although only to a limited extent due to the ongoing physical growth of the world´s technosphere. New products, e.g. for ICT and energy conversion require rising amounts of rare metals such as platinum, which are associated with significant ecological rucksacks in mining and refining.

Metals will remain an important element of the industrial metabolism also in the future. SUMR will become rather important with regard to the management of metal flows and may be expected to contribute to

- reduce the requirements for primary raw materials (ores) through
  a. increased recycling beyond the production phase: product take-back systems, integrated product design and product management for reuse, recovery and recycling need to be further developed,
  b. mitigating net addition to stock in industrial, transition and developing countries (by moderating demand for buildings and infrastructures, resource efficiency of construction and dwelling);
  c. increased material efficiency in production and consumption;

- a world-wide preference of mining and refining at locations and with technologies which carry comparably low ecological rucksacks[17] and lay proof of regionally sound reinvestment of economic gains[18].

SUMR for metals will require the involvement of international activities due to international commodity markets and the global disparities of resource extraction and consumption on the one hand and the environmental and socio-economic implications on the other hand.

Non-metallic construction minerals
The use of minerals such as cement, sand and gravel, limestone etc. is linked to the construction of buildings and infrastructures. In the ongoing phase of physical growth, demand for these materials will further grow esp. in developing and transition countries. Some industrial countries still have low recycling of construction and demolition waste, and even high rates convey a distorted picture because demolishing waste from buildings is used for road construction (down-cycling). Developing countries are at the risk to adopt highly material intensive modes of construction in private and public buildings as well as infrastructures. In contrast to metals, supply is and may be expected to remain regional or continental. There are some examples that gravel is transported across Europe by truck due to local shortages, and models of construction flows for instance for the Netherlands show that this country will always be dependant from importing construction minerals from neighbouring countries only for maintenance of the existing buildings and infrastructures (Müller in print).

Construction minerals will be further used in the future, although with a significant lower share of primary minerals. SUMR is expected to

- reduce the requirements for primary non-metallic minerals through
  a. mitigating net addition to stock in industry, transition and developing countries (by moderating demand for buildings and infrastructures, resource efficiency of construction and dwelling);
  b. increased recycling: construction design and management for reuse, recovery and recycling (esp. high level recycling) need to be further developed,
  c. increased material efficiency in production and consumption;

- foster the preference of regional quarry locations and technologies with comparably low ecological rucksacks (incl. low transport burden).

[17] The ecological rucksack of mining in terms of unused extraction (the total extraction indicates the potential of local environmental disruption) varies not only between metals, but may also vary by orders of magnitude for the same metal depending on location and technologies used; see e.g. the case of gold mining (Valdivia 2005).
[18] See Extractive Industries Review (2003).

Engineering standards and textbooks will have to be further developed, and endemic experience in the various countries, e.g. to construct temperate houses in tropical countries without air condition system and with local materials in durable fashion should be rediscovered.

Materials specific versus broad scale policy approach

There is a debate on whether the flows of single materials (e.g. copper, zinc, cadmium, aluminium, steel) should be analysed in detail for specific environmental impacts, before any instruments designed to control these specific impacts could be employed. Following this line of thinking, several problems occur.

The complexity trap
If only thirty to fifty most important base materials were to be considered which may be associated with two to ten major impacts, each occurring at various stages of the life-cycle, sixty to five hundred specific standards would have to be established by probably rather detailed regulations. The governmental effort, time needed, financial requirements for preparing, implementing and controlling might be enormous. This kind of material and impact specific regulatory approach will sooner or later find its limits with regard to efficiency and effectiveness.

Trying to control specific impacts of single materials and processes is associated with a high risk of problem shifting due to substitution, if no general guideline is followed which prevents the adoption of particular solutions with counterproductive effects at the macro level. For instance, if regulative pressure would be exerted against a selected base material such as copper, this metal would be, as far as technological feasible and economically viable, substituted for other metals, which will be associated with other problems at other places, and the outcome with regard to global environmental pressure may remain highly uncertain. Another principle problem with the control of specific impacts is that only a certain portion of environmental impacts can be measured in a way which is attributable to products and processes; and that precautionary action cannot be based on this type of re-active approach.

Setting the incentive framework
Alternatively, the policy *framework* could be adjusted in a way which mobilizes the know-how and motivation of actors and industry and households through appropriate incentives to find technological and institutional solutions which drive the socio-industrial metabolism towards the sustainability corridor. For that purpose it may not be so important to meet single critical levels for particular substance flows (while overlooking others) rather than to apply techniques and management practices which altogether lead to lower environmental pressure, improved socio-economic performance and more equitable resource use at the global level.

A key strategy, necessary for all major resource groups is to enhance materials efficiency. Policy programmes to foster the broad-scale search for efficiency options in industry and households may be deemed one appropriate approach to induce technological and managerial innovations which are not confined to single material flows but would have a significant effect on the use of all major materials used.

Steering towards the right direction: dematerialization

Although various individual material flows exert different environmental impacts, the multitude of processes and technologies, and the mix of materials leads to the phenomenon that at the macro level primary material consumption is correlated with the sum of all environmental pressures which currently can been accounted for.

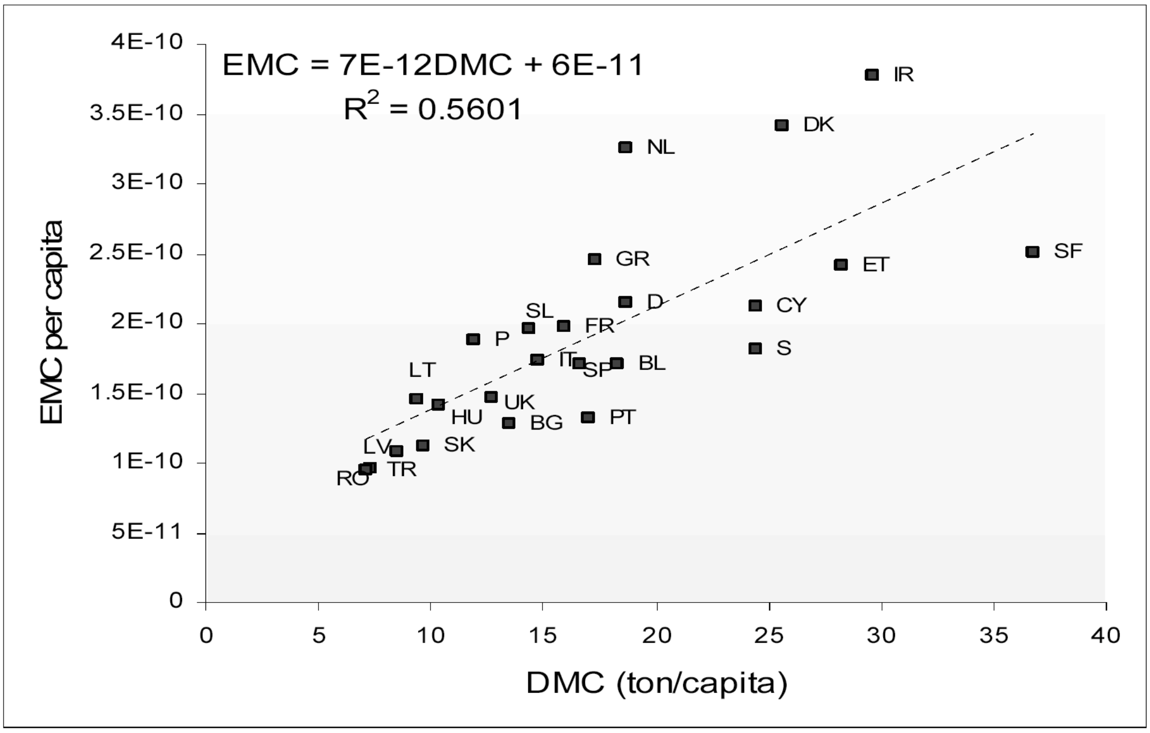

FIGURE 5: At the national level, Domestic Material Consumption is an indicator of overall environmental pressure, measured as EMC (Environmentally weighted Material Consumption index) (Voet et al. 2005)

Voet et al. (2005) defined the Environmentally weighted Material Consumption index (EMC) for national economies. The index was based on the apparent consumption of 31 selected base materials by country. Each material was attributed its life-cycle-wide environmental impacts based on state-of-the-art LCA methodology. The 13 impact categories were equally weighted against each other. The EMC was significantly correlated with the Domestic Material Consumption (DMC) indicator (FIGURE 5). The DMC accounts for the sum of domestic used primary material extraction plus imports minus exports in mass units. It is a measure of the total mass which flows — with varying retention time within the stock — through the production and consumption system of a country, indicating the potential mass flow of waste and emissions. Because the imports are dominated by raw materials and exceed the exports by far, the DMC of European countries is also related to the amount of primary materials used for domestic purposes.

Despite the deficiencies of the LCA based method[19] which renders the EMC an estimate the approach reflects what currently can be accounted for based on available data on well-known first order environmental impacts. The results show that lower (primary) material consumption is indeed associated with lower overall environmental pressure and resulting impacts (as far as these can be quantified). Thus, *less is better* also for the environment provided that a dematerialization will not lead to more hazardous compounds used.

Although Voet et al. (2005) found a slight increase of more polluting materials (which corroborates the findings e.g. of Schütz et al. 2004 on the increased shift of resource intensive raw materials and semi-manufactures to regions exporting to the EU), there is no significant indication that a reduction of material consumption should increase this trend. Provision may be taken by monitoring environmental pressure indices such as the EMC every five years, as complement to the more regular accounting of DMI, DMC and TMR.

Dematerialization: essential supplement of the strategy mix

We understand dematerialization of the socio-industrial metabolism as a process which leads to lower primary materials consumption and requires an increase of materials and resource efficiency in the production and consumption system (it does not necessarily mean a reduced use of material goods). The dematerialization strategy complements the strategies of detoxification and regeneration of resources (Table 1).

Dematerialization compensates for other strategies' metabolic deficiencies
In contrast to pollution control, recycling and the shift to regrowing resources, dematerialization is not confined to specific materials (although measures to increase materials efficiency can focus on material intensive technologies and branches). Whereas recycling tends to require the highest degree of vertical integration of processes along the production-consumption process chain, the reduction of direct material input for certain processes through higher efficiency will also mitigate up-stream material and resource flows.

Table 1: Complementary strategies for sustainable use and economy-wide management of resources

	Detoxification	**Regeneration of resources**		**Dematerialization**
	Elimination/ control of hazardous or interfering substances/ materials	Reuse & Recycling (Rematerialization)	Use of naturally renewable (regrowing) resources	Reduction of primary material input through increased material/ resource efficiency
Reducing substance/material related health & environmental hazards	+++	+	+	++
Sustaining the structure of the socio-industrial metabolism	–	+++	+++	+/–
Adjusting net throughput of the metabolism to more sustainable levels	–	+	–	+++
Mitigating physical expansion of technosphere (net addition to stock)	–	–	–	++
Opportunities for socio-economic benefits (innovation, competitiveness, employment)	(–)/+	++	+(+)	++(+)
Potential to minimize problem shifting across substances/ materials, env. problems, regions, over time	– –	+	+/–	++
+++: very relevant; ++: relevant; +: weakly relevant; +/–: ambigous; –: not relevant; – –: possibly counterproductive				

Dematerialization through reduced material input tends to lower the outflows of residuals to the environment, independant of their route of entry. This strategy has a profound potential for horizontal integration across various material flows, which is absent in the detoxification and recycling strategy. Substance specific pollution control is the adequate means to reduce health hazards and direct environmental effects such as eutrophication. A broad-scale dematerialization would, nevertheless, tend to reduce the

[19] e.g. limited number of materials considered, average impact coefficients for various countries due data availability, lacking consideration of societal priorities for weighting, confinement to direct impacts where quantitative coeffiecents have been available

amount resource extraction and releases to the environment, thus also contributing to reduce the overall environmental impact (see FIGURE 5).

The structure of the socio-industrial metabolism in terms of non-renewable vs. renewable basis would be affected mainly by the recycling and biomass strategy. Without specific priority setting, a non-targeted dematerialization would not be expected to change the physical structure of the metabolism. Dematerialization, however, may be regarded as essential for adjusting the primary material intake and subsequent throughput of the metabolism to more sustainable levels, both at the national and international level. And it may be the only effective means to mitigate the growth of the material stock.

Dematerialization also offers socio-economic benefits

At the same time, the increase of material and resource efficiency and the required technological and institutional change seems to provide significant opportunities for multiple-win options, e.g. with regard to increased competitiveness through innovation, and social benefits through more employment. Policies for pollution control, recycling and the shift to bio-economy have proven to contribute to technical innovation and new markets (e.g. Porter and Linde 2000, Jänicke and Jacob 2002). Policies for dematerialization, if carefully designed, offer to provide an even higher benefit.

Material costs of manufacturing industry usually exceed labour costs and provide significant potentials for the increase of total factor productivity (Bleischwitz 1998). The effect of a future governmental programme to induce the increased use of these potentials was first modelled by Fischer et al. (2004) for the Germany economy. Assuming a 20% linear reduction of material costs in manufacturing industry and public administration between 2004 and 2015 would altogether lead to a growth of GDP and labour productivity while reducing prices. The effect on employment would be positive, if the increase in (nominal) labour productivity (through increased material productivity) were not fully transfered to higher wages in order to allow for investments into resource efficient technologies. That indicates that dematerialization could also provide socio-economic benefits depending on the concrete design of governmental action and flanking measures of the labour market[20].

[20] See also Aachen Foundation (2005).

Table 2: Socio-economic effects of a dematerialization through reduced material costs in comparison to business as usual (Fischer et al. 2004)

Variable	Scenario I Imperfect markets	Scenario II wage competition	Scenario III price competition
In current prices		Relative deviation in %	
Consumption goods	–1.87	–3.25	–7.17
Production prices	–1.29	–2.55	–7.49
Wage rate	6.52	0.29	4.00
Labour productivity	12.12	7.37	14.77
In constant prices			
Gross Output	3.30	2.38	6.41
Gross Domestic Product	10.48	9.37	13.83
Private consumption	13.36	10.96	15.44
State consumption	5.98	5.20	11.41
Equipment investment	3.71	3.33	5.95
Construction investment	3.25	2.87	4.44
Exports	0.69	0.71	2.20
Imports	–2.07	–3.16	–2.50
In current prices		Absolute deviation in bill. Euro	
State net financial investment	1.28	21.24	–5.72
		Absolute deviation in persons	
Wage and salary earners (rounded to 10 000)	–480 000	760 000	–300 000

General conditioning and specific regulation of the socio-industrial metabolism

From a regulatory point of view, we distinguish between metabolic conditioning on the one hand and fine regulation on the other hand[21]. The *conditioning* of the socio-industrial metabolism aims to increase its “fitness”, “shape” and “condition” for sustainability. Similar to a health cure, the current metabolism which is too “fat” (accumulating materials) and suffers from too high and too fast throughput, needs to be developed towards a leaner and more mature state with lower resource inputs which are used much more efficiently. The *specific regulation*, in contrast, resembles the control of physiological errands of single substances or the optimization of selected material flows. Like with medical strategies, curative action to suppress unhealthy symptoms with fine tuning methods, are often bound to fail as long as the general condition remains unhealthy. Increasing the fitness of the socio-industrial metabolism for sustainability, in

[21] In former work, terms such as "coarse tuning vs. fine tuning" were applied (Bringezu 2000).

a kind of preventive manner, e.g. through higher efficiency of resource use, may also be expected to reduce the requirements for curative action, e.g. through reduced generation of waste and emissions.

Metabolic conditioning

The aim is to develop the volume, structure, international performance and growth dynamics of the socio-industrial metabolism in a sustainable way towards maturity. For orientation may serve the accounts of the main material flows and resource groups such as biomass, fossil fuels, metals, non-metallic minerals, national and transnational resource requirements, and NAS. Policy instruments to be developed under a national and EU resource management programme, may comprise measures which are unspecific for materials, i.e. can be applied for all materials, or instruments specific for *resource groups*. Materials, energy and land use should be considered in an integrated manner. Resource intensive industries could be supported by materials efficiency programmes to find and use options for dematerialization. Demand of resource intensive products could be muted (e.g. by re-visiting subsidies and checking public procurement and investments). R&D and curricula for SUMR need to be further developed as well.

Specific regulation

The aim is to further (a) eliminate and control potentially disruptive use of substances, i.e. health hazards (e.g. cadmium), environmental hazards (e.g. nitrogen), technical obstacles (e.g. zinc[22]); (b) optimize selected base material flow systems (e.g. steel, copper, platinum group metals), in order to reduce environmental hot spots along the production-consumption chain, enhance recycling, reduce losses, increase life-cycle-wide resource efficiency, and to check alternatives for the provision of final demand. Here, single substances, specific material flows and environmental impacts[23] provide the basis for orientation. Policies may include command and control measures (e.g. bans of hazardous substance use), technical standards, information for producers and consumers.

In order to find the potentials for technological and institutional improvements for increased resource and materials efficiency, more information is required on the main product groups, their material flows through production and consumption and the resulting domestic and foreign resource requirements. Information is needed which potentials could be mobilized where in the process chain (mining/harvest, manufacturing, final production, use, recycling, final disposal), how (more efficient process chain management, process chain design, product design and management etc.) and through which support (e.g. getting prices right through reduction of counterproductive

22 Which may be an obstacle to steel recycling.

23 According to the DPSIR indicator system, the life-cycle-wide analysis or material system analysis is more related to the disclosure of pressures than impacts.

subsidies). Here, governmental action should support further research and development to elucidate such potentials and to trigger innovation towards the sustainability corridor.

At the same time, material flow systems of base materials could be further analyzed. For instance, Moll et al. (2005b) studied the iron and steel material flow system of the EU and described the main options to synergistically reduce resource requirements and the emission of green house gases. For copper, alternative technologies which substitute the burying of cables for improved patterns of deployment which allow easy recovery after decades of use, provide another example (Behrendt et al. 2000). Copper is also important with regard to international sustainable resource management. Schüller (2006) studied different production routes of primary copper and their environmental impacts induced by production in Chile and Germany. He provided a thorough basis for the assessment of technological development scenarios which can used by industry in both countries to improve the environmental performance of their facilities within the global production network and to reduce negative impacts of their products from cradle-to-commodity. Saurat (2006) analyzed the flows of platinum group metals (PGM) used for production and consumption in Europe. He elaborated scenarios of future demand for PGM for car catalysts and fuel cells which provide important information on environmental impacts and up-coming scarcities of PGM as well as possibilities to improve the environmental performance of PGM production and use. In general, the analysis and assessment of selected material flows requires appropriate involvement of industry experts in order to make use of the expertise on the multitude of technological options for improvement.

Altogether, both the general conditioning and the regulation of specific materials and substances are complementary strategies. Both are necessary but as a stand-alone insufficient to sustain the socio-industrial metabolism.

As required by TSSURE, it seems indeed necessary to improve the knowledge gathering and information on material flows in production and consumption, also on specific material flow systems and their interaction with the environment and the economy. However, this need not be, even must not be regarded as a priori condition for governmental action, rather than the result of efficient and effective setting of the policy framework.

Action required

Policy development towards SUMR will have to rely on three pillars: (1) goals, targets and indicators on where to go (the latter not only for measuring progress but also for orientation), (2) improved information how to do better for all relevant actors at different levels, and (3) effective incentives for the actors to move.

Policy objectives and targets

In the EU and at the international level, a common understanding of the sustainability corridor and the key role of increased resource and materials efficiency still needs to be developed. Countries should agree on medium to long-term targets of materials and energy productivity, absolute level of resource and material consumption and the proportion of domestic vs. foreign resource use, the share of renewables and the proportion of sustainable cultivation of renewables. Current EU and OECD activities on MFA and the measurement of resource productivity may serve as a basis for orientation and further development. Scenarios modelling the potentials for change and how they could be phased in over time can further improve target-setting. Joining forces between departments responsible for waste on the one hand and sustainable production and consumption on the other hand seems promising, as well as the orientation on targets already established by some OECD member countries (e.g. Japan, Germany).

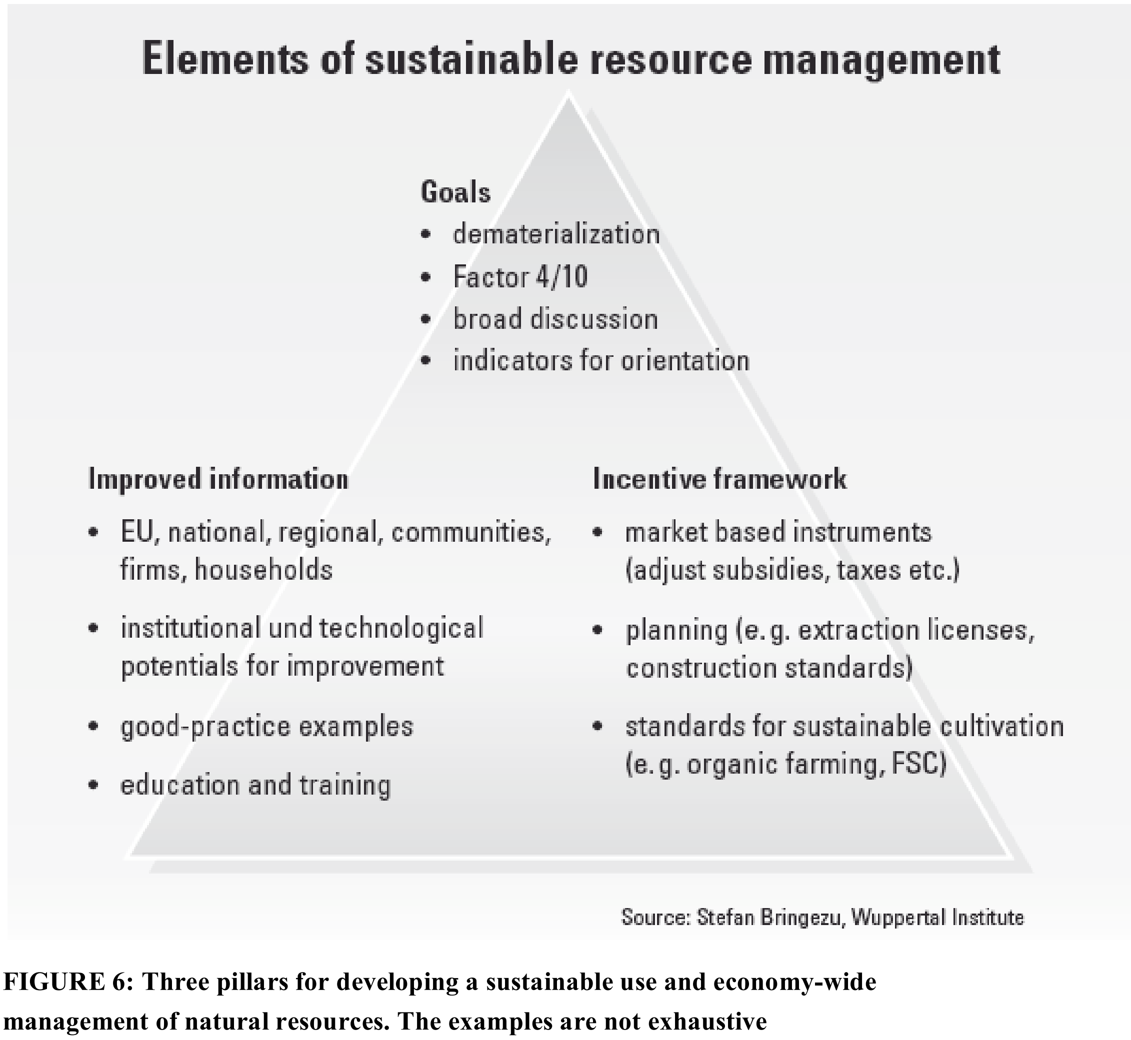

FIGURE 6: Three pillars for developing a sustainable use and economy-wide management of natural resources. The examples are not exhaustive

Improved information

Decision makers in GOs, industry and NGOs require information not only on the performance of the economy as a whole but also on the material use and resource productivity of industry sectors, and the technological and institutional potentials for improvement. Here research is ongoing, e.g. at the Wuppertal Institute, but a broader scale knowledge gathering seems necessary. An exchange between European, national and international institutions (e.g. EEA, ETC-RWM, Eurostat, OECD), is recommended where sectoral statistics on physical indicators are being explored (e.g. by NAMEA), indicators on domestic versus foreign resource use are under development and further research on specific material flows (e.g. iron/steel, copper) is under consideration.

With regard to globalization and the increasing importance of foreign trade, a public data basis should be developed on the cradle-to-product environmental impacts of traded commodities; existing coefficients of the Wuppertal Institute' data base on total resource requirements of raw materials and semi-manufactures can serve as a pilot and starting point for further development. Assembling data on foreign material flows usually exceeds the capacities of national statistical offices, although those may have an interest to use those data in order to account for global impacts of domestic activities; therefore, transnational cooperation will be required to set up in a stepwise manner such a data base on physical implications of international trade. Such a data base could be supplemented by information on supply security of strategic raw materials.

An intergovernmental expert panel on national and international resource management could review and foster knowledge for further policy support. Within the ETAP framework, a technology platform on material efficiency and sustainable resource use could be formed to provide information, data, procedural guidance and good practice examples. On the long run, a European or an international agency for SUMR could be established to gather, review and provide relevant information and reference data on the various aspects of the actual use and management of resources in production and consumption and the options for further improvement.

Actors in industry und households also need focused and practical information, e.g., resource efficiency labels, benchmarks, and individual analyses on their firm or residence and on specific products. Communication of good practice examples, and the development of education and training programmes would also belong to the tasks of an institutionalized resource policy.

Promoting the incentive framework

Some countries have started to explore new institutional settings towards SUMR in production and consumption, especially to increase resource and materials efficiency. The Japanese government initiated research on institutional options to foster materials efficiency[24]. North-Rhine Westphalia (one of the German Länder) had successfully

[24] http://www.esri.go.jp

introduced an efficiency agency[25] to support SMEs in order to find potentials for cost reduction and minimization of waste, energy, water and material consumption. The German national government has launched a materials efficiency programme for the manufacturing sector. The concept comprises support of SMEs for efficiency checks, the establishment of a national material efficiency agency[26], a network of experts and a material efficiency award (Arthur D. Little et al. 2005). So far, these activities are focussing on direct material use in industry, and the effect on life cycle-wide total resource requirements and potential shifts to other regions is not yet part of official monitoring programmes.

Some countries have already implemented economic instruments (e.g. UK aggregate tax) in order to increase the price of primary resources in order to set incentives for higher efficiency, lower environmental pressure, increased recycling and fostering of innovation. If no accompanying measures to increase materials efficiency in industry are taken, such economic instruments may only shift sourcing and related problems to other regions through increased imports. The ETC on Resource and Waste Management has started to review the effectiveness of relevant economic instruments (Legg et al. 2006), which may contribute to further development of an appropriate incentive framework towards SUMR in the future.

Conclusions

- A dematerialization in terms of higher materials efficiency and lower primary resource requirements seems to be a necessary complement to pollution control, recycling and renewables oriented strategies in order to sustain the bio-physical basis of society and economy.
- Starting from status quo and current trends in the EU (which are comparable to other industrial countries), there is evidence that less material consumption is good for the environment, there are strong arguments that a dematerialization would be profitable for the economy, and there are indications that it could be designed in a way that is also beneficial for society.
- SUMR requires progress with regard to a couple of interlinked, potentially synergistic key elements with regard to improved targets, information, and incentives. A major challenge for developing these key elements for future EU and national policies will be to minimize the shifting of environmental and socio-economic problems to other regions.

[25] http://www.efanrw.de
[26] http://www.demea.de

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References

Aachen Foundation – Aachener Stiftung (Hrsg.) (2005): Ressourcenproduktivität als Chance – Ein langfristiges Konjunkturprogramm für Deutschland. Aachen

Arthur D. Little, FhG-ISI, Wuppertal Institute (2005): Studie für die Konzeption eines Programms zur Steigerung der Materialeffizienz in mittelständischen Unternehmen. Abschlussbericht. Projekt-Nr. 2404 des Bundesministeriums für Wirtschaft und Arbeit, Berlin

Ayres, R.U., Ayres, L. (Ed.)(2002): Handbook of Industrial Ecology. Cheltenham

Barbier, E.B. (1989): Economics, Natural Resource Scarcity and Development. Conventional and Alternative Views. London

Behrendt, S., Klinski, S., Naumann, A., Scharp, M. Zwisele, B. (2000): Machbarkeitsstudie für eine stoffstrombezogene Abfallwirtschaftspolitik. UBA-Forschungsbericht 29831756, IZT, ARGUS, Jungnickel&Partner, Berlin

Bleischwitz, R. (2005): Beyond Material Efficiency: realignment of the international raw material markets. Yearbook 2004/05 Wuppertal Institute: 94–98

Bleischwitz, R. (1998): Ressourcenproduktivität. Innovationen für Umwelt und Beschäftigung. Berlin

Bleischwitz, R., Hennicke, P. (Eds.)(2004): Eco-Efficiency, Regulation and Sustainable Business. Towards a Governance Structure for Sustainable Development. Cheltenham, Northampton

Bringezu, S. (2006): Interpretation and use of material flow and resource productivitiy indicators. Background paper for the OECD workshop on material flow and resource productivity indicators - interpretation and use, 16–17 May 2006, Rome. ENV/EPOC/SE(2006)2

Bringezu, S. (2004): Erdlandung. Navigation zu den Ressourcen der Zukunft. Stuttgart

Bringezu, S., (2002): Towards Sustainable Resource Management in the European Union. Wuppertal Papers 121, Wuppertal

Bringezu, S. (2000): Ressourcennutzung in Wirtschaftsräumen. Springer: Berlin/Heidelberg/ New York

Bringezu, S.; Steger, S. (2005): Biofuels and Competition for Global Land Use. In: Berger, Hartwig; Prieß, Rasmus (Eds.) "Bio im Tank. Chancen – Risiken – Nebenwirkungen". Conference documentation of conference series "Kyoto+ Lab" of the Heinrich-Böll-Foundation and the European Climate Forum. Global Issue Papers No. 20: pp. 64–79

Bringezu, S.; Schütz, H.; Moll, S. (2003). Rationale for and Interpretation of Economy-wide Material Flow Analysis and Derived Indicators. *Journal of Industrial Ecology* **7** (2), 43–64

CEC – Commission of the European Communities (2005a): Thematic Strategy on sustainable use of natural resources. COM(2005) 670final. Brussels

CEC – Commission of the European Communities (2005b): Integrated Guidelines for Growth and Jobs (2005-2008). COM(2005) 141 final. Brussels

CEC – Commission of the European Communities (2004a): Facing the challenge. The Lisbon strategy for growth and employment. Report from the High Level Group chaired by Wim

Kok. Luxembourg: Office for official publications of the European Communities. http://europa.eu.int/comm/lisbon_strategy/index_en.html

CEC – Commission of the European Communities (2004b): Protecting the Environment and Economic Growth: trade-off or growth enhancing structural adjustment, in: European Commission, The EU Economy: 2004 Review, Brussels, 26 October 2004 ECFIN (2004) REP 50455-EN

CEC - Commission of the European Communities (2003): Towards a Thematic Strategy on the Sustainable Use of Natural Resources. Communication from the Commission to the Council and the European Parliament. COM(2003) 572final. Brussels

Daly, H. E. (1992): Steady-State Economics: Concepts, Questions, Policies. GAIA 1: 333–338

DLR, ifeu, Wuppertal Institut (2003): Ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien in Deutschland. Forschungsbericht an das Ministerium für Umwelt, Naturschutz und Reaktorsicherheit. Stuttgart, Heidelberg, Wuppertal

EEA – European Environment Agency (2005): Sustainable use and management of natural resources. EEA Report No 9/2005, Copenhagen

EEA – European Environment Agency (2003): Europe's environment: the third assessment. Environmental assessment report no. 10. Luxembourg: Office for official publications of the European Communities. http://reports.eea.eu.int/environmental_assessment_report_2003_10/en

Eurostat – Statistical Office of the European Communities (Ed.) (2001a). Economy-wide material flow accounts and derived indicators (Edition 2000). A methodological guide. European Communities, Luxembourg

Eurostat (2001b): Material use indicators for the European Union, 1980-1997 No. 2/2001/B/2

Extractive Industries Review (2003): Striking a Better Balance – The World Bank Group and Extractive Industries: The Final Report of the Extractive Industries Review

Fischer, H., Lichtblau, K., Meyer, B., Scheelhaase, J. (2004): Wachstums- und Beschäftigungs-impulse rentabler Materialeinsparungen. Wirtschaftsdienst 2004 (4): 247–254

Jänicke, M. / Jacob, K. (2002). Ecological modernization and the creation of lead markets. FU Berlin, FFU rep 03/2002

Legg, D., Zoboli, R., Bleischwitz, R., Skovgaard, M., Herczeg, M., Leveson-Gower, H. (2006): Economic instruments to promote material resource efficiency. Main report from phase 1. ETC/RWM working paper 2006/1, Copenhagen

Millennium Ecosystem Assessment (2005): Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Matthews, E., C. Amann, S. Bringezu, M. Fischer-Kowalski, W. Hüttler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, D. Rogich, H. Schandl, H. Schütz, E. van der Voet, H. Weisz (2000), The weight of nations: Material outflows from industrial economies, World Resources Institute Report, Washington D. C.

Moll, S., Bringezu, S., Schütz, H. (2005a): Resource Use in European Countries. An estimate of material and waste streams in the Community, including imports and exports using the instrument of material flow analysis. Wuppertal Report No. 1, Wuppertal

Moll, S., Acosta, J., Schütz, H. (2005b): Iron & Steel – A Material System Analysis. European Topic Centre on Resource and Waste Management. Copenhagen

Müller, D. B.: Stock dynamics for forecasting material flows – A case study for housing in The Netherlands. Ecological Economics, in print

OECD – Organisation for Economic Co-operation and Development (2005): Material flows and related indicators. Inventory of country activities. Working Group on Environmental Information and Outlooks. ENV/EPOC/SE(2004)3/Final/add, 23-Feb-2005, Paris

Porter, M., v. d. Linde, C. (2000): Green and competitive: ending the stalemate. In: E.F.M. Wubben (Ed.). The Dynamics of the Eco-Efficient Economy, Cheltenham/Northampton, pp. 33–55

Rocholl, M., Giljum, S., Behrens, A., Schlegelmilch, K. (2006): Factor X and the EU: How to make Europe the most resource and energy efficient Economy in the World. A review of policies and legislative initiatives of the EU which could contribute to increasing the energy and resource efficiency of the European Union. Aachen Foundation, Aachen

Saurat, M. (2005). Material Flow Analysis and Related Environmental Impact Assessment of PGM in Europe. Master Thesis, Chalmers University of Technology and Wuppertal Institute, in prep

Schmidt-Bleek, F. (1993): MIPS Re-visited. Fres. Env. Bull. 2: 407–412

Schmidt-Bleek, F. (1992): Will Gemany remain a good place for Industry? The Ecological Side of the Coin. Fres. Env. Bull. 1: 417–422

Schüller, M. (2006): Material Flow Analysis of Selected Primary Copper Routes: Chile and Germany. Diplomarbeit im Studiengang Umweltschutztechnik, Fakultät für Bau- und Umweltingenieurwesen, Universtität Stuttgart, erstellt am Wuppertal Institut in Kooperation mit dem Institut für Kunststoffkunde und Kunststoffprüfung, Abt. Ganzheitliche Bilanzierung, Stuttgart

Schütz, H., Moll, S., Bringezu, S. (2004): Globalisation and the Shifting Environmental Burden. Material Trade Flows of the EU. Which Globalisation is Sustainable? Wuppertal Papers No. 134e, Wuppertal: Wuppertal Institute

UN (2002): The Johannesburg Declaration on Sustainable Development. Political Declaration of the World Summit on Sustainable Development, August, 26th – September, 4th, Johannisburg

UNEP (2002): Global Environment Outlook 3. Earthscan, London

US Geological Survey (2004), 20th century U.S. mineral prices decline in constant dollars, by Sullivam, D., Sznopek, J.L. and Wagner L.A., report 00-389, Washington D.C.

Valdivia, S. (2005): Ecological Backpack and Life Cycle Inventories of a Precious Metal – Case Study: Gold from Peru. Unpublished report. Pontifical Catholic University of Peru

Van der Voet, E., van Oers, L., Moll, S., Schütz, H., Bringezu, S., de Bruyn, S., Sevenster, M., Warringa, G. (2005): Policy review on decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries. CML report 166, Leiden: Institute of environmental sciences (CML), Leiden: Leiden University, Department Industrial Ecology, 2005. http://www.leidenuniv.nl/cml/ssp/

Weizsäcker, E. U., Lovins, A.B., Lovins, L.H. (1995). Factor Four. Doubling Wealth Halving Resource Use, London

Wuppertal Institute, German Technical Cooperation GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) (2004): Towards renewable energy systems: Integrating renewable energy and energy efficiency is the key. Discussion paper for the International Conference “Renewables 2004”, Eschborn